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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	10/616,097	SUN ET AL.	
	Examiner	Art Unit	
	EDNA WONG	1795	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *21 January 2008*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *8-10,20-22,31-33 and 37-59* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *8-10,20-22,31-33 and 37-59* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

Continued Examination Under 37 CFR 1.114

A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after final rejection. Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, the finality of the previous Office action has been withdrawn pursuant to 37 CFR 1.114. Applicant's submission filed on February 21, 2008 has been entered.

This is in response to the Amendment After Final dated January 21, 2008. The text of those sections of Title 35, U.S. Code not included in this action can be found in a prior Office action.

Response to Arguments

<u>Claim Rejections - 35 USC § 103</u>

I. Claims **8-9 and 37-44** have been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1) and **Wang et al.** (US Patent No. 6,528,412 B1).

The rejection of claims 8-9 and 37-44 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al. and Wang et al. has been withdrawn.

II. Claim **10** has been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1) and **Wang et al.** (US Patent No. 6,528,412 B1) as applied to claims 8-9 and 37-44 above, and further in view of **Nagai et al.** (US Patent No. 6,709,563 B2).

The rejection of claim 10 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al. and Wang et al. as applied to claims 8-9 and 37-44 above, and further in view of Nagai et al. has been withdrawn.

III. Claims **20-21 and 45-52** have been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1) and **Wang et al.** (US Patent No. 6,528,412 B1).

The rejection of claims 20-21 and 45-52 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al. and Wang et al. has been withdrawn.

IV. Claim **22** has been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1) and **Wang et al.** (US Patent No. 6,528,412 B1) as applied to claims 20-21 and 45-52 above, and further in view of **Nagai**

et al. (US Patent No. 6,709,563 B2).

The rejection of claim 22 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al. (US Patent No. 6,432,821 B1) and Wang et al. as applied to claims 20-21 and 45-52 above, and further in view of Nagai et al. has been withdrawn.

V. Claims **31-32 and 53-58** have been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1) and **Wang et al.** (US Patent No. 6,528,412 B1).

The rejection of claims 31-32 and 53-58 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al. and Wang et al. has been withdrawn.

VI. Claim **33** has been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1) and **Wang et al.** (US Patent No. 6,528,412 B1) as applied to claims 31-32 and 53-58 above, and further in view of **Nagai et al.** (US Patent No. 6,709,563 B2).

The rejection of claim 33 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al. and Wang et al. as applied to claims 31-32

and 53-58 above, and further in view of Nagai et al. has been withdrawn.

VII. Claim **59** has been rejected under 35 U.S.C. 103(a) as being unpatentable over **Miura et al.** (US Patent Application Publication No. 2003/0155247 A1) in combination with **Dubin et al.** (US Patent No. 6,432,821 B1), **Wang et al.** (US Patent No. 6,528,412 B1) and **Dubin** (US Patent Application Publication No. 2004/0108217 A1).

The rejection of claim 59 under 35 U.S.C. 103(a) as being unpatentable over Miura et al. in combination with Dubin et al., Wang et al. and Dubin has been withdrawn.

Response to Amendment

Claim Objections

Claim **8, 20 and 59** are objected to because of the following informalities:

<u>Claim 8</u>

line 14, recites "to ***deposit*** a copper seed layer across the onto ***the barrier surface***".

line 15, recites "wherein the copper seed layer is ***formed*** across the entire ***barrier layer surface***".

line 16, recites "the copper seed layer ***disposed*** on ***the substrate***".

Please amend the claim language to be consistent.

<u>Claim 20</u>

lines 8-10, recites "exposing the substrate to a complexed copper solution ***comprising complexed copper ions reducing the complexed copper ions*** with a first electrical bias to form a copper seed layer on the barrier surface" which is a *run-on* sentence.

lines 9-10, recite "to ***form*** a copper seed layer on ***the barrier surface***".

lines 11-12, recite "the copper seed layer … ***disposed*** on ***the substrate***".

Please amend the claim language to be consistent.

<u>Claim 59</u>

lines 10-11, recite "the copper seed layer … ***disposed*** on ***the substrate***".

Claim 59, lines 8-9, recite "to ***deposit*** a copper seed layer onto ***the ruthenium barrier layer***".

Please amend the claim language to be consistent.

Appropriate correction is required.

Claim Rejections - 35 USC § 112

I. Claims **31-33 and 53-58** are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject

matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention.

Claim 31

lines 14-16, recites "wherein the copper seed layer is directly formed on the barrier surface without intervening layer disposed therebetween".

Applicants' specification, pages 1-18, does not disclose wherein the copper seed layer is directly formed on the barrier surface without intervening layer disposed therebetween. Thus, there is insufficient written description to inform a skilled artisan that applicant was in possession of the claimed invention as a whole at the time the application was filed.

The Examiner has carefully considered the entire specification as originally filed, however, there is found no literal support in the specification for the newly added limitations in amended claim 31. Applicants have not provided the page number and line numbers from the specification as to where the newly added limitations are coming from. *Ex parte Grasselli*, 231 USPQ 393 (Bd. App. 1983) *aff'd mem.* 738 F.2d 453 (Fed. Cir. 1984).

II. Claims **37, 47-51 and 54-58** are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claim 37

lines 1-2, recite "wherein the copper seed layer ***is deposited on the entire barrier surface***".

Claim 8, line 15, recites "wherein the copper seed layer ***is formed across the entire barrier layer surface***".

It is unclear how claim 37 further limits claim 8.

Claim 47

lines 1-2, recite "wherein ***the complexed copper solution comprises*** copper citrate".

Claim 20, lines 8-9, recite "***a complexed copper solution comprising*** complexed copper ions".

It is unclear how claim 47 further limits claim 20.

It is unclear how the same complexed copper solution can have two separate and independent compositions.

Claim 54

lines 1-2, recite "wherein ***the complexed copper solution comprises*** copper citrate".

Claim 31, lines 8-11, recite "***a complexed copper solution comprising*** complexed copper ions derived from a copper source selected from the group

consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof".

It is unclear how claim 54 further limits claim 31.

It is unclear how the same complexed copper solution can have two separate and independent compositions.

Claim Rejections - 35 USC § 103

I. Claims **8-9 and 37-44** are rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** ('600) in combination with **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1), **Dubin et al.** (US Patent No. 6,432,821 B1) [*Dubin '821*] and **Nogami et al.** (US Patent No. 6,242,349 B1).

JP '600 teaches a method for depositing a copper-containing seed layer onto a barrier layer, comprising:

(a) providing a substrate **11** (= a semiconductor substrate with an insulator layer) comprising the barrier layer **21** disposed on a substrate surface (Fig. 1(3)), wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface (= a tungsten nitride film and a tungsten film) [page 5, [0026]];

(b) exposing the substrate to a first copper solution comprising copper ions and having a pH (= a copper sulfate system electrolytic plating liquid, e.g., Enthone-OMI

CuBath Series), wherein the copper ions are derived from a copper source (= copper sulfate) [page 4, [0022]]; and

(c) applying a first electrical bias across the substrate surface (= from a plating current of 2.83 A = I = V/R, Ohm's law) [page 4, [0022]] to chemically reduce the copper ions to deposit a copper seed layer **23** onto the barrier surface **21** (Fig. 1(4)); and

(d) depositing a copper bulk-fill layer **24** (= a metal skin) by:

(i) exposing the substrate to a third copper solution containing free-copper ions (= a copper sulfate system electrolytic plating liquid, e.g., Microfab Cu2000 Series); and

(ii) applying a third electrical bias across the substrate surface (= from a plating current of 2.83 A = I = V/R, Ohm's law) to deposit the copper bulk-fill layer **24** onto the copper seed layer (pages 4-5, [0024]).

The copper seed layer **23** is deposited on the entire barrier surface **21** (Fig. 1(5)).

The barrier layer consists essentially of cobalt, ruthenium, nickel, or tungsten (= a tungsten film) [page 5, [0026]].

The method described by JP '600 differs from the instant invention because JP '600 does not disclose the following:

a. Wherein the pH is a pH value of less than 7, as recited in claim 8.

b. Wherein the copper ions are complexed copper ions, as recited in claim 8.

c. Wherein the copper source is selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof, as recited in claim 8.

d. Wherein the copper source is copper citrate, as recited in claim 38.

e. Wherein the first copper solution contains a copper concentration within a range from about 0.02 M to about 0.8 M, as recited in claim 39.

f. Wherein the pH value is within a range from about 4.5 to about 6.5, as recited in claim 43.

g. Wherein the first electrical bias generates a current density of less than about 10 mA/cm^2 across the substrate surface, as recited in claim 40.

h. Wherein the first electrical bias generates a current density within a range from about 0.5 mA/cm^2 to about 3 mA/cm^2 across the substrate surface, as recited in claim 41.

JP '600 teaches that a copper sulfate system electrolytic plating liquid, e.g., Enthone-OMI CuBath Series. The plating current value was set as 2.83 A (page 4, [0022]).

Like JP '600, Wang teaches electrodepositing a copper-containing seed layer onto a barrier layer (page 6, [0046]).

Wang teaches a copper sulfate system electrolytic plating liquid wherein:

- the pH value is less than 7 (= a pH of 6) [pages 3-4, [0031]];
- the copper ions are complexed copper ions (= the amine-containing

compound is used in an amount sufficient to complex the copper ion in solution such that precipitation of the copper ion is reduced or eliminated) [pages 4-5, [0037]];

• the copper source is selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof (= copper citrate) [page 3, [0027]];

• the copper source is copper citrate (page 3, [0027]);

• the first copper solution contains a copper concentration within a range from about 0.02 M to about 0.8 M (= a concentration of 0.005 to 0.5 M) [page 3, [0028]]; and

• the pH value is within a range from about 4.5 to about 6.5 (= a pH of ≥ 6) [pages 3-4, [0031]].

The first electrical bias generates a current density of less than about 10 mA/cm^2 across the substrate surface (= 0.1 to 25 mA/cm^2) [page 6, [0046]].

The first electrical bias generates a current density within a range from about 0.5 mA/cm^2 to about 3 mA/cm^2 across the substrate surface (= 0.1 to 25 mA/cm^2) [page 6, [0046]].

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the first copper solution described by JP ‘600 with (a) to (h) above because such are conditions that would have electrodeposited a copper seed layer onto a barrier layer as taught by Wang (pages 3-4, [0027] and [0031]; pages

4-5, [0037]; and page 6, [0046]).

i. Depositing a copper gap-fill layer by:

(i) exposing the substrate to a second copper solution containing free-copper ions; and

(ii) applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 8.

JP ‘600 teaches a dual damascene process (page 2, [0007]; and Figs. 1 and 2]).

Like JP ‘600, Dubin ‘821 teaches an electroplating process for filling damascene structures. Dubin ‘821 teaches that a plating program in which an initiation, or seed layer repair, operation is performed by forcing a first forward current, a second forward current is then forced to superfill features less than 0.3 microns in width, and finally, a third forward current is forced to perform a bulk fill operation is a known conventional plating program for filling damascene structures (col. 3, line 66 to col. 4, line 10; and Fig. 2).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the method described by JP ‘600 by depositing a copper gap-fill layer by steps (i) and (ii) above because modifying the method with a halfway fill comprising a second forward current (and bias) and a complete fill comprising a third forward current (and bias) would have eliminated thin seed layer dissolution and would have superfilled the smallest features first and then the largest

features in order to provide the desired surface morphology as taught by Dubin '821 (col. 3, line 66 to col. 4, line 10; col. 7, lines 12-38; and Figs. 2 and 7).

Furthermore, it has been shown that the transpositioning of varying steps, or varying the details of a process, as by adding a step or splitting one step into two does not avoid obviousness where the processes are substantially identical or equivalent in terms of function, manner and result. *General Foods Corp. v. Perk Foods Co.* (DC NIll 1968) (157 USPQ 14); *Malignani v. Germania Electric Lamp Co.*, 169 F. 299, 301 (D.N.J. 1909*); Matrix Contrast Corp. v. George Kellar*, 34 F.2d 510, 512, 2 USPQ 400, 402-403 (E.D.N.Y 1929); *Hammerschlag Mfg. Co. v. Bancroft*, 32 F. 585, 589 (N.D.Ill.1887); *Procter & Gamble Mfg. Co. v. Refining*, 135 F.2d 900, 909, 57 USPQ 505, 513-514 (4th Cir. 1943); *Matherson-Selig Co. v. Carl Gorr Color Gard, Inc.*, 154 USPQ 265, 276 (N.D.Ill.1967).

As to the second copper solution comprising free-copper ions, free-copper ions are inherently present in a highly acidic or highly basic copper plating solution because it is the copper ions that are deposited on the substrate to form the copper seed layer.

j. Annealing the copper seed layer disposed on the substrate, as recited in claim 8.

Like JP '600, Nogami teaches an electroplating process for filling damascene structures (col. 5, lines 38-51). ***Annealing the seed layer*** results in two positive advantages. Firstly, annealing ***induces grain growth*** of the seed layer forming a stable

grain structure and dominant (111) orientated grains. Consequently, Cu or a Cu alloy plated on the annealed seed layer exhibits a larger grain size with a higher (111) crystallographic texture, thereby improving electromigration resistance. Secondly, annealing the seed layer advantageously *increases bonding* between the seed layer and underlying barrier metal layer before electroplating. Consequently, copper atoms at the seed layer/barrier metal layer interface do not migrate during electroplating or subsequent to electroplating, thereby reducing void formation at the interface and, hence, improving electromigration resistance (col. 5, lines 21-37).

When employing *a Cu* or Cu alloy *layer*, annealing can be conducted at a temperature of about 100°C to about 400°C, e.g. about 150°C, for about thirty seconds to about thirty minutes, e.g. about one minute, *in a vacuum or in an atmosphere containing argon, nitrogen or hydrogen*.

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the copper seed layer disposed on the substrate described by JP '600 by annealing the copper seed layer disposed on the substrate because annealing the seed layer would have induced grain growth of the seed layer and increased bonding between the seed layer and underlying barrier metal layer leading to improved electromigration resistance as taught by Nogami (col. 5, lines 21-37).

k. Wherein the copper seed layer has a thickness less than about 200 Å, as

recited in claim 42.

JP ‘600 teaches that the copper seed layer has a thickness of 30 nm (= 300 Å) [page 4, [0021]].

Wang teaches that the copper seed layer has a thickness ***up to*** 2000 Å. Such seed layers provide a sufficiently conductive layer for subsequent electroplating (pages 5-6, [0045]).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the thickness of the copper seed layer described by JP ‘600 with wherein the copper seed layer has a thickness less than about 200 Å because thin copper deposits, such as in the range of ***5*** to 2000 ***Å*** or even from ***50*** to 1500 ***Å*** would have been suitable thicknesses for use as metal seed layer to provide a sufficiently conductive layer for subsequent electroplating as taught by Wang (pages 5-6, [0045]).

II. Claim **10** is rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** (‘600) in combination with **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1), **Dubin et al.** (US Patent No. 6,432,821 B1) [*Dubin ‘821*] and **Nogami et al.** (US Patent No. 6,242,349 B1) as applied to claims 8-9 and 37-44 above, and further in view of **Nagai et al.** (US Patent No. 6,709,563 B2).

JP ‘600, Wang, Dubin ‘821 and Nogami are as applied above and incorporated herein.

The method described by JP ‘600 differs from the instant invention because JP ‘600 does not disclose wherein at least one leveling agent is added to the second copper solution to form the third copper solution, as recited in claim 10.

Like JP ‘600, Nagai teaches depositing a copper bulk-fill layer (step 4: second-stage plating (filling with copper)) [col. 16, lines 8-19; and Fig. 19]. In the second-stage plating section **22***b*, a copper sulfate plating liquid (second plating liquid) containing copper sulfate and sulfuric acid, and having excellent leveling property is used as the plating liquid **45** (col. 16, lines 40-43). The “leveling property” refers to a property of giving a flat plating surface. *The use of the plating liquid having an excellent leveling property can retard the growth of plating at the inlet of a fine recess*. This makes it possible to fully fill the fine recesses with copper uniformly without formation of any void, and further flatten the plating surface (col. 17, line 64 to col. 18, line 2).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the second copper solution described by JP ‘600 and Dubin with wherein at least one leveling agent is added to the second copper solution to form the third copper solution because the use of a plating liquid having an excellent leveling property would have retarded the growth of plating at the inlet of a fine recess. This would have made it possible to fully fill the fine recesses with copper uniformly without formation of any void, and further flatten the plating surface as taught by Nagai (col. 17, line 64 to col. 18, line 2).

III. Claims **20-21 and 45-52** are rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** ('600) in combination with **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1), **Dubin et al.** (US Patent No. 6,432,821 B1) [*Dubin '821*] and **Nogami et al.** (US Patent No. 6,242,349 B1).

JP '600, Wang, Dubin '821 and Nogami are as applied for the reasons as discussed above and incorporated herein.

IV. Claim **22** is rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** ('600) in combination with **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1), **Dubin et al.** (US Patent No. 6,432,821 B1) [*Dubin '821*] and **Nogami et al.** (US Patent No. 6,242,349 B1) as applied to claims 20-21 and 45-52 above, and further in view of **Nagai et al.** (US Patent No. 6,709,563 B2).

JP '600, Wang, Dubin '821, Nogami and Nagai are as applied for the reasons as discussed above and incorporated herein.

V. Claims **31-32 and 53-58** are rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** ('600) in combination with **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1) and **Dubin et al.** (US Patent No. 6,432,821 B1) [*Dubin '821*].

JP '600, Wang and Dubin '821 are as applied for the reasons as discussed above and incorporated herein.

VI. Claim **33** is rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** ('600) in combination with **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1) and **Dubin et al.** (US Patent No. 6,432,821 B1) [*Dubin '821*] as applied to claims 31-32 and 53-58 above, and further in view of **Nagai et al.** (US Patent No. 6,709,563 B2).

JP '600, Wang, Dubin '821 and Nagai are as applied for the reasons as discussed above and incorporated herein

VII. Claim **59** is rejected under 35 U.S.C. 103(a) as being unpatentable over **JP 2002-76000** ('600) in combination with **Dubin** (US Patent Application Publication No. 2004/0108217 A1) [*Dubin '217*], **Wang et al.** (US Patent Application Publication No. 2005/0020068 A1), **Nogami et al.** (US Patent No. 6,242,349 B1) and **Chen et al.** (US Patent No. 7,192,494 B2).

JP '600 teaches a method for depositing a copper-containing seed layer onto a barrier layer, comprising:

(a) providing a substrate **11** (= a semiconductor substrate with an insulator layer) having a barrier layer **21** disposed on a substrate surface (page 3, [0014] and [0015]; and Fig. 1(3));

(b) exposing the substrate to a first copper solution comprising copper ions and having a pH (= a copper sulfate system electrolytic plating liquid, e.g., Enthone-OMI CuBath Series) [page 4, [0022]];

(c) applying a first electrical bias across the substrate surface (= from a plating current of 2.83 A = I = V/R, Ohm's law) [page 4, [0022]] to chemically reduce the copper ions and to deposit a copper seed layer **23** onto the barrier surface **21** (Fig. 1(4)); and

(d) depositing a copper gap-fill layer **24** (= a metal skin) by:

(i) exposing the substrate to a second copper solution containing free-copper ions (= a copper sulfate system electrolytic plating liquid, e.g., Microfab Cu2000 Series); and

(ii) applying a second electrical bias across the substrate surface (= from a plating current of 2.83 A = I = V/R, Ohm's law) to deposit the copper gap-fill layer **24** onto the copper seed layer **23** (pages 4-5, [0024]).

The method described by JP ‘600 differs from the instant invention because JP ‘600 does not disclose the following:

a. Wherein the barrier layer is a ruthenium barrier layer, as recited in claim 59.

JP ‘600 teaches that although a tantalum nitride film was used for the barrier layer **21**, it is possible to use other materials (page 5, [0026]).

Like JP ‘600, Dubin ‘217 teaches an electroplating process for filling damascene structures. Dubin teaches that the barrier layer can include any one of the following

materials: tantalum, tungsten, titanium, *ruthenium*, molybdenum, and their alloys with nitrogen, silicon and carbon (page 2, [0021]).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have barrier layer described by JP '600 with wherein the barrier layer is a ruthenium barrier layer because ruthenium would have been functionally equivalent as a barrier layer as taught by Dubin '217 (page 2, [0021]).

It has been held that the selection of a known material based on its suitability for its intended use supports a prima facie obviousness determination (MPEP §§ 2144.06 and 2144.07).

b. Wherein the pH is a pH value of less than 7, as recited in claim 59.

JP '600 teaches that a copper sulfate system electrolytic plating liquid, e.g., Enthone-OMI CuBath Series, was used for the plating solution (page 4, [0022]). The plating current value was set as 2.83 A (page 4, [0022]).

The copper sulfate system electrolytic plating liquid disclosed by JP '600 inherently has a pH.

Like JP '600, Wang teaches electrodepositing a copper-containing seed layer onto a barrier layer (page 6, [0046]).

Wang teaches a copper sulfate system electrolytic plating liquid wherein:

- the pH value is less than 7 (= a pH of 6) [pages 3-4, [0031]].

It would have been obvious to one having ordinary skill in the art at the time the

invention was made to have modified the pH described by JP ‘600 with wherein the pH is a pH value of less than 7 above because such a condition would have electrodeposited a copper seed layer onto a barrier layer as taught by Wang (pages 3-4, [0027] and [0031]; pages 4-5, [0037]; and page 6, [0046]).

c. Annealing the copper seed layer in an oxygen free environment disposed on the substrate, as recited in claim 59.

Like JP ‘600, Nogami teaches an electroplating process for filling damascene structures (col. 5, lines 38-51). *Annealing the seed layer* results in two positive advantages. Firstly, annealing *induces grain growth* of the seed layer forming a stable grain structure and dominant (111) orientated grains. Consequently, Cu or a Cu alloy plated on the annealed seed layer exhibits a larger grain size with a higher (111) crystallographic texture, thereby improving electromigration resistance. Secondly, annealing the seed layer advantageously *increases bonding* between the seed layer and underlying barrier metal layer before electroplating. Consequently, copper atoms at the seed layer/barrier metal layer interface do not migrate during electroplating or subsequent to electroplating, thereby reducing void formation at the interface and, hence, improving electromigration resistance (col. 5, lines 21-37).

When employing *a Cu* or Cu alloy *layer*, annealing can be conducted at a temperature of about 100°C to about 400°C, e.g. about 150°C, for about thirty seconds to about thirty minutes, e.g. about one minute, *in a vacuum or in an atmosphere*

containing argon, nitrogen or hydrogen.

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the copper seed layer disposed on the substrate described by JP '600 by annealing the copper seed layer disposed on the substrate because annealing the seed layer would have induced grain growth of the seed layer and increased bonding between the seed layer and underlying barrier metal layer leading to improved electromigration resistance as taught by Nogami (col. 5, lines 21-37).

d. Annealing the copper gap-fill layer disposed on the substrate, as recited in claim 59.

Like JP '600 , Nogami teaches an electroplated copper to be used to form a metal interconnect (col. 5, lines 48-60). The electroplated copper is subjected to an annealing step under an annealing gas environment (col. 5, lines 61-63). The microstructure of the copper layer can be stabilized and a reduced film resistivity and/or enhanced reflectivity of the copper layer can be achieved (col. 3, lines 6-8).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the copper gap-fill layer disposed on the substrate described by JP '600 by annealing the copper gap-fill layer disposed on the substrate because this would have stabilized the microstructure of the copper layer and would have achieved a reduced film resistivity and/or enhanced reflectivity of the copper layer

as taught by Nogami (col. 3, lines 6-8).

Any inquiry concerning this communication or earlier communications from the examiner should be directed to EDNA WONG whose telephone number is (571) 272-1349. The examiner can normally be reached on Mon-Fri 7:30 am to 4:00 pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nam Nguyen can be reached on (571) 272-1342. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

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/Edna Wong/
Primary Examiner
Art Unit 1795

EW
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